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Modeling the Polarization of Dusty Scattering Cones in Active Galactic Nuclei

René W. Goosmann

Astronomical Institute, Academy of Sciences, Prague, Czech Republic

C. Martin Gaskell

Dept. Physics & Astronomy, Univ. of Nebraska, Lincoln, NE, USA

Masatoshi Shoji

Astronomy Department, Univ. of Texas, Austin, TX, USA

Abstract. We have used the STOKES radiative transfer code, to model polarization induced by dust scattering in the polar regions of Active Galactic Nuclei (AGN). We discuss the wavelength-dependence of the spectral intensity and polarization over the optical/UV range at different viewing angles for two different types of dust: a Galactic dust model, and a dust model inferred from extinction properties of AGN. The STOKES code and documentation are freely available at http://www.stokes-program.info/.

Spectropolarimetry delivers important results helping to explain the geometry of AGN (e.g. Antonucci 2002). The spectropolarimetric properties of individual objects are generally complicated and need to be disentangled by accurate modeling. The new Monte-Carlo radiative transfer code, STOKES, is designed to simulate polarization by scattering in a wide variety of astrophysical contexts. The program allows the user to define different emission and scattering geometries and solve the radiative transfer in 3D. It takes into account polarization induced by scattering off free electrons and dust grains. The dust composition includes carbonaceous and siliceous grains and the grain size distributions parameterized by truncated power laws. The code measures light travel times and thus can be used to model polarization reverberation mapping (Shoji, Gaskell, & Goosmann 2005).

Here we use STOKES to model the polarization expected from scattering in dusty, centrally-illuminated double cones of AGN. We follow the same procedure as in Goosmann & Gaskell (2007). The optical depth of one cone along the symmetry axis is $\tau_{\rm V} = 0.3$ for the V-band, its half-opening angle equals $\theta_C = 30°$. Whilst in Goosmann & Gaskell (2007) we assume a dust composition reproducing the extinction in our Galaxy, we here apply a different dust parameterization, that inferred from AGN extinction curves (Gaskell et al. 2004; Gaskell & Benker 2007), which show a flatter far-UV slope than those for our Galaxy. Our AGN dust model implemented here contains 85% "astronomical silicate" and 15% graphite. The distribution, $n(a)$, of grain radii, a, obeys to the power-law $n(a) \propto a^{-2.05}$. The resulting polarization and flux spectra, normalized to the central illuminating flux, are shown in Fig. 1 (left).

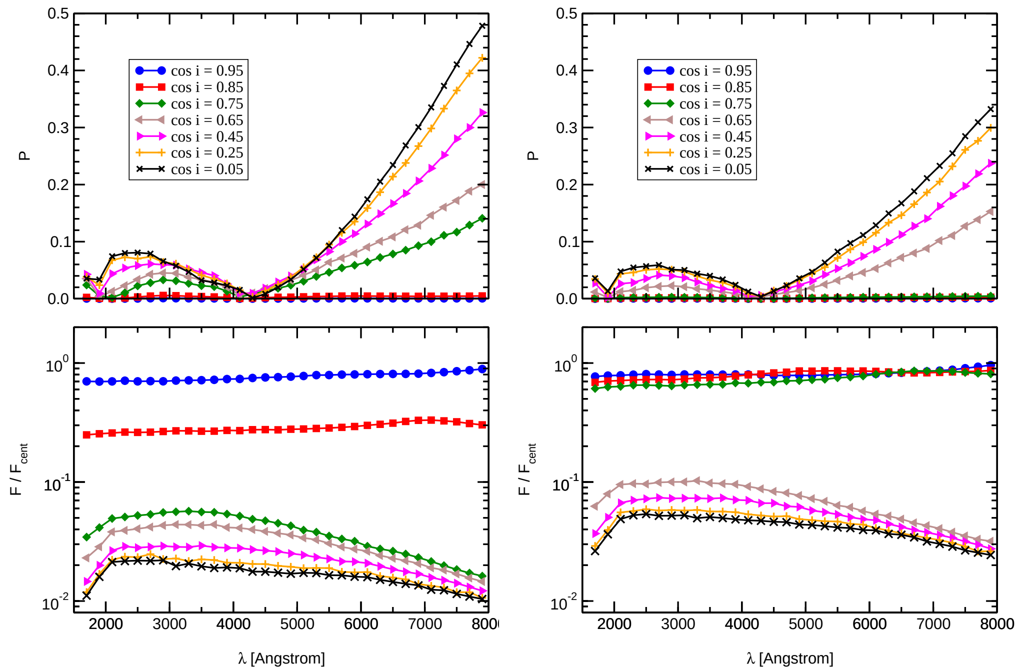

Figure 1. Modeling a dusty double cone of half-opening angle $\theta_C = 30°$ (left) and $\theta_C = 45°$ (right). Top: polarization, P. Bottom: the fraction, F/F_*, of the central flux, F_*, seen at different viewing inclinations, i.

Comparison to the results in Goosmann & Gaskell (2007) reveals some clear differences: The polarization spectra are weaker at shorter wavelengths than for the Galactic dust model. Around 4000 Å, the polarization curves drop down to nearly zero and then they increase again steeply to longer wavelengths. For Galactic dust the polarization spectra show a more gradual increase over the whole wavelength range considered. Because of the larger average grain size, the scattering efficiency of the AGN dust is significantly smaller. The flux seen beyond the edge of the cone, for $i > \theta_C$, is therefore low.

We find similar trends for a larger half-opening angle of $\theta_C = 45°$, as shown in Fig. 1 (right). However, the obtained polarization percentages are lower, than for the narrower cone, because the observer detects the integration of a broader range of polarization vectors. The scattered flux at $i > 45°$, on the other hand, is higher due to higher coverage of the central source.

References

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